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Energy-Related Carbon Dioxide Emissions in Alberta

1988 - 2005

Alberta

ENERGY
Energy Efficiency Branch

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Energy Efficiency Branch
Alberta Department of Energy
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Executive Summary

An inventory of manmade carbon dioxide emissions for Alberta has been completed by the Alberta Department of Energy. The inventory attempts to quantify the level of carbon dioxide emissions from all energy-related fuel use in the province. The year 1988 is used as a base and emissions growth to 2005 are forecast using Energy Resources Conservation Board data.

Emissions are allocated to all energy end use sectors. This approach, rather than calculating emissions by fuel type, allows for future analysis of energy end use reduction potential. For this reason emissions from centrally-generated electricity are attributed to the end use sectors similar to fossil fuel emissions.

The inventory analysis provides the following information:

a) Alberta's total CO_2 emission in 1988 is estimated to be 124 megatonnes. This is forecast to grow to 177 megatonnes by the year 2005.

b) The largest source of CO_2 emissions is the energy industry, accounting for about 42% of the total.

c) Emissions from the residential, commercial, transportation, and other industry sectors are all very similar, accounting for 12 to 16% of the total each.

Alberta is the highest per capita emitter of carbon dioxide in Canada, and second highest overall after Ontario. This is due to both the presence of the energy industry and the fact that most of the province's electricity generation is from coal.

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1. INTRODUCTION

This study provides an inventory of energy-related carbon dioxide (CO_2) emissions for Alberta. The analysis encompasses the period between 1988 and 2005. A similar study was originally by the Alberta Department of Energy in June, 1989. This report updates and expands upon the original.

An inventory of CO_2 emissions is of interest because of current concerns with global warming and the atmospheric greenhouse effect. Carbon dioxide generated from both natural sources and human activities is the largest single contributor to greenhouse gases in the atmosphere. Man-made CO_2 emissions are predominately from the combustion of fossil fuels in the production and use of energy. These growing energy-related emissions are suspected to be causing an imbalance in atmospheric heating, potentially leading to global warming.

There is little historical data regarding Alberta's current CO_2 emissions or those predicted in the future. However, relatively good information on energy use in the province is available through Alberta's Energy Resources Conservation Board (ERCB). In most cases the conversion from energy use to CO_2 emissions is straightforward. The study therefore, focuses mainly on compiling energy production and utilization data.

To estimate future emissions a forecast is required. It is provided by the ERCB Report 89-A - *Energy Requirements in Alberta, 1989 to 2003*. That report is revised and published regularly by the Board, and is based on information supplied by a range of organizations involved in energy production, transportation, supply and use. The ERCB report forecasts to the year 2003. This study chose 2005 as its forecast end point because that year had been suggested as a target for emission reductions by the Changing Atmosphere Conference held in Toronto in 1988.

Energy use data is most frequently discussed in terms of fuel types. However the inventory segregates energy use and ultimately CO_2 emissions by end use sector. This has been done to assist in any future analysis of the potential for emissions reduction through a variety of demand-side initiatives such as energy efficiency and fuel switching.

a) Scope of the Study

The inventory includes CO_2 emissions generated mainly from energy-related fuel use and combustion in Alberta. It includes emissions from energy production activities, electric generation, energy transmission, and all energy end-use sectors.

Not all emissions are combustion related. For example sizeable volumes of raw CO_2 are released from underground formations in the production of oil and gas. Industrial operations also emit CO_2 from natural gas used as a feedstock, such as in the production of hydrogen through steam reformation. Some CO_2 is released from limestone and other materials in the processing of cement, lime and magnesium. All the above sources are considered in this study.

Not included are CO_2 emissions from wood. It is debateable whether or not emissions from wood, wood waste, and slash burning should be part of this inventory. Organic material eventually decomposes naturally and emits approximately the same volume of CO_2 as if it were burned. However, the rate of emission from wood is considerably speeded up when combusted. While this issue is beyond the scope of the present inventory, it may bear investigation in the future.

Emissions from municipal solid waste incineration are also not included, for similar reasons.

b) Methodology

Considerable effort was applied to allocating energy use data to end-use sectors. The ERCB's Integrated Model of Alberta, on which the energy requirements for the province are forecast, is an econometric model designed to look at aggregate energy use. It divides the analysis into broad categories such as the residential, commercial, industrial and transportation sectors.

This study attempts to distribute the data sectorally as much as possible to permit better analysis of the sources of CO_2 emissions. The distribution is difficult for several reasons. First, the ERCB model by its nature tends to disregard discrepancies in energy use data within sectoral boundaries as long as the aggregate total is reasonable. Secondly, detailed energy use statistics are frequently not available from Statistics Canada or other sources.

For this study the years 1988 and 2005 were chosen as endpoints. Actual energy use statistics were available for 1988 at the time the analysis was done (first quarter of 1990), and these numbers were used in the inventory. The data for 2005 is based on the ERCB 89-A forecast. In most cases actual energy use data for 1988 fit well into the Board model. Occasionally there were significant differences. In those instances an attempt was made to rationalize the difference between the 1988 actual and 1988 forecast data. This meant occasionally altering the Board's forecast data in both 1988 and 2005 if the actual data was felt to be more representative. Thus the energy requirements forecast in this inventory do not exactly match the 89-A forecast.

Energy use sectors were broken down into subsectors as much as possible, depending on the availability of data and the need for definition to permit any future analysis of emission reduction potential. For example, the commercial sector was divided into the subsectors of commercial buildings, education buildings, hospitals, other commercial, and street lighting. In most cases the subsectors represented groupings of facilities or industries with similar energy use profiles.

Once a distributed energy use inventory by subsector was determined, the energy data was converted to CO_2 emissions by applying fuel-specific conversion factors. In most cases the factors, expressed in megatonnes of CO_2 per petajoule of energy (Mt/PJ), are simply the higher heating value of the fuel, assuming 100% combustion. Emission coefficients for process gas or feedstock gas were more difficult to determine. Process gas from oil sands, for example, is a mix of constituents, often varying with time. Carbon dioxide emissions from feedstock gas are process dependent. The emission factors by fuel type are described in more detail in **Appendix B.**

Emissions from electricity generation are handled somewhat differently. In order to properly quantify the emissions from each subsector, it is necessary to allocate centrally-generated emissions based on sectoral electricity use. This is done by calculating an empirical CO_2 conversion factor for electricity consumption. The factor is calculated by dividing the total megatonnes of CO_2 emissions from coal and gas-fired generating facilities by the total secondary electric energy demand in gigawatt hours. Since Alberta exports little electric energy, this calculation is considered an appropriate way of allocating emissions to the various subsectors within the province.

Some electricity is produced via cogeneration in industrial operations such as oil sands and petrochemical plants. For the purposes of this study such electricity use was given an emission factor of zero. The fuel used for cogeneration (normally gas) was attributed to fuel rather than electricity use and the appropriate CO_2 conversion factor applied.

c) Sources of Data

The majority of energy use data was taken directly from the ERCB 89-A Report *Energy Requirements for Alberta - 1988 to 2003*. In some areas where further breakdown was necessary Statistics Canada sources were used. Information on CO_2 generated from non-energy activities such as cement, lime and magnesium production was supplied by RTM Engineering Ltd. of Calgary.

In some cases the ERCB data was redistributed within a specific sector to better reflect end use in the subsectoral areas. An example is the transportation sector where energy use data for commercial and public vehicles had been allocated on the basis of pump sales. Since better data in terms of vehicle stock were available, the energy use was redistributed more accurately on this basis.

2. ENERGY INVENTORY

The detailed energy inventory for Alberta is presented in tabular form in **Appendix A.** Total energy use in 1988 is estimated to be 2064 petajoules (PJ), increasing to 2918 PJ in the year 2005. **Figure 1** shows the growth profile of energy over the period.

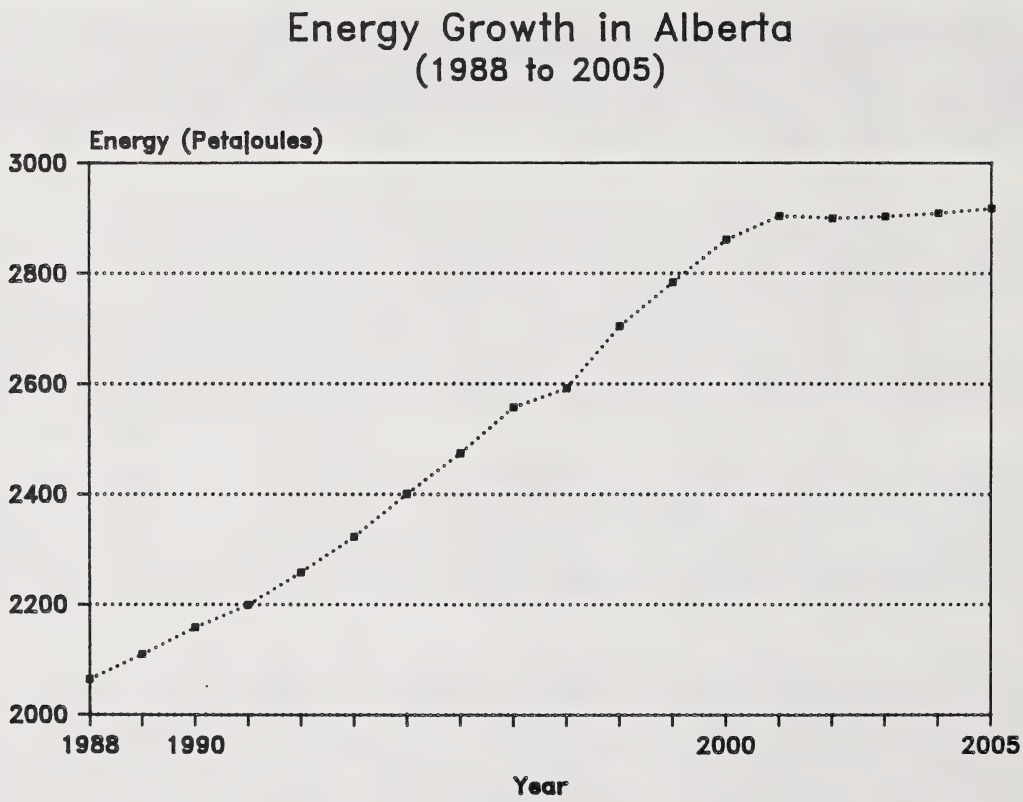

Figure 1

The shape of the curve in **Figure 1** reflects the energy requirements forecast of the ERCB. Provincial energy demand increases relatively constantly until the turn of the century, at which point demand is forecast to largely level off. Carbon dioxide emissions growth essentially tracks energy growth.

The energy requirements forecast uses the ERCB's high-case scenario which makes the following assumptions:

- real GDP growth rate . . . . . = 3.2%/year
- energy demand growth rate . . . . . = 2.6%/year
- energy prices in 1988 . . . . . = $16.00/bbl of WTI crude
- energy prices in 2003 . . . . . = $29.46/bbl of WTI crude
- population growth . . . . . = 1.3%/year

Table I on the following page provides a summary of the energy inventory data. Part (i) of the table presents the data categorized by sector, with energy use for electricity generation shown as one of the sectors. Part (ii) is a similar analysis but in this case energy for electric generation has been distributed to each sector, proportional to the secondary electric energy demand for that area. Part (iii) of the table analyses the data by fuel type. **Figure 2** provides a graphical summary of the 1988 and 2005 sectoral energy use with electric generation shown separately.

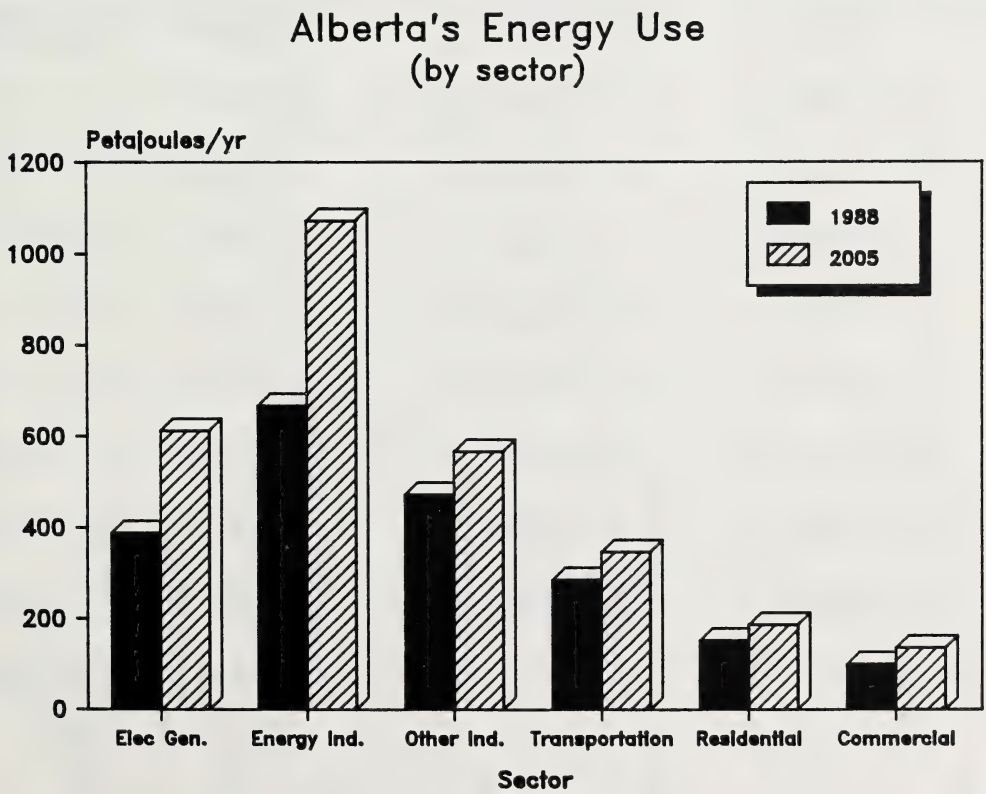

Figure 2

TABLE I - SUMMARY OF ENERGY USE BY SECTOR
(all numbers in PJs)

i) By Sector - electric generation separate

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Residential	152	155	157	159	161	163	166	169	171	173	175	177	179	181	182	183	184	186
Commercial	100	103	105	108	110	113	115	118	120	123	125	126	128	130	131	132	134	136
Energy Industry	667	687	712	731	762	795	848	891	925	939	971	1031	1063	1084	1068	1068	1069	1072
Other Industry	472	483	486	487	491	496	497	497	512	513	561	562	591	595	595	585	575	566
Transportation	285	287	286	288	291	296	301	306	312	317	324	326	329	332	335	339	342	346
Electric Generation	388	395	411	426	442	460	474	494	517	527	547	561	571	583	589	596	604	612
Total	2064	2109	2158	2199	2258	2323	2401	2474	2557	2592	2704	2784	2861	2904	2899	2903	2909	2918

ii) By Sector - electricity use allocated to sectors

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Residential	228	232	236	240	244	249	253	257	263	268	273	278	281	285	287	291	294	297
Commercial	208	210	216	222	229	236	241	248	257	263	272	277	282	287	292	298	304	311
Energy Industry	778	805	836	858	895	933	992	1041	1080	1095	1132	1194	1227	1249	1231	1230	1231	1233
Other Industry	529	539	545	550	557	566	570	577	596	600	652	657	690	696	699	691	683	676
Transportation	285	287	287	289	292	297	301	307	313	318	325	327	329	333	336	340	343	347
Transmission Losses	36	37	38	40	41	43	43	45	47	48	50	51	52	53	53	54	54	54
Total	2064	2109	2158	2199	2258	2323	2401	2474	2557	2592	2704	2784	2861	2904	2899	2903	2909	2918

iii) By fuel type

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
fuel gas	961	965	1000	1026	1064	1104	1163	1219	1238	1251	1267	1301	1325	1330	1321	1316	1312	1310
process gas	86	96	94	97	98	98	98	98	101	103	106	101	107	117	113	112	112	112
feedstock gas	258	287	287	288	288	288	289	283	305	310	368	397	426	431	431	429	427	426
propane	38	38	39	39	40	41	42	42	43	44	45	45	46	47	48	48	49	50
diesel	95	96	97	97	98	99	100	102	104	106	109	110	111	112	112	113	115	116
kerosene	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
HFO	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
LFO	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2
coke	47	45	44	39	41	42	42	42	42	42	47	52	59	61	60	60	60	60
synthetic crude	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
gasoline	174	174	171	171	172	173	175	177	179	180	183	184	183	182	182	182	182	182
aviation	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
turbo	25	26	28	29	31	33	34	35	37	38	40	40	41	42	44	45	46	48
NGV	0	0	0	1	1	1	2	2	2	2	3	3	4	5	7	8	8	9
coal	369	371	386	401	416	432	445	464	494	504	526	539	548	566	571	579	586	594
total	2064	2109	2158	2199	2258	2323	2401	2474	2557	2592	2704	2784	2861	2904	2899	2903	2909	2918

The energy industry category in Figure 2 consists of usage by the following sectors: oil fields, oil refineries, oil sands, gas processing and reprocessing, coal mines, pipelines, and gas flaring. The other industry category refers to energy use in the petrochemical, pulp and paper, cement plant, and other industrial subsectors. Electric generation includes both coal and natural gas energy used in generation plants as well as line losses in the transmission of electricity. It does not include additional fuel used in industrial cogeneration, which is attributed to sectoral fuel demand.

The total energy used in Alberta in 1988 is calculated to be 2064 PJ. This number represents the energy used or burned in one form or another that contributed to CO_2 emissions. As such it is neither correct to refer to it as the province's secondary energy requirement (since it includes all fuel used for electricity generation), nor the primary energy requirement (since it does not include large volumes of uncombusted fuel exported or used in other forms).

By 2005 the total energy use is forecast to be 2918 PJ, a growth of 41%. The largest growth is in the energy industry (primarily due to oil sands developments) and in electric generation because of rapidly growing electric demand.

In terms of fuel type, natural gas used as fuel in all its forms represents by far the largest energy source, at 961 PJ. Coal and feedstock gas are next at 369 PJ and 258 PJ respectively.

3. CARBON DIOXIDE INVENTORY

To convert energy use to carbon dioxide emissions, the appropriate CO_2 conversion factor for each fuel type is applied. **Appendix B** details the CO_2 conversion factors used in the study and discusses how they were determined.

The result is the CO_2 inventory presented in detail in **Appendix C.** In addition to the quantities of CO_2 related to fuel combustion from the energy inventory, the CO_2 inventory also includes raw CO_2 released in hydrocarbon production and from non-energy sources such as cement and lime manufacturing.

Table II provides a summary of the emissions, similar in format to Table I. Total CO_2 emissions for 1988 are calculated to be 124.3 megatonnes By 2005 emissions are estimated to be 176.8 megatonnes, a growth of 42%.

It is of interest to compare Alberta with the rest of Canada. As shown in **Figure 3**, the 1988 Alberta CO_2 emission of 124.3 Mt represents slightly more than 20% of the Canadian total, although some caution must be exercised as the national total is not well studied. The reasons for Alberta's prominence are a large contribution from the energy industry (which produces much energy for export) and a similarly large contribution from predominately coal-fired electric generation facilities.

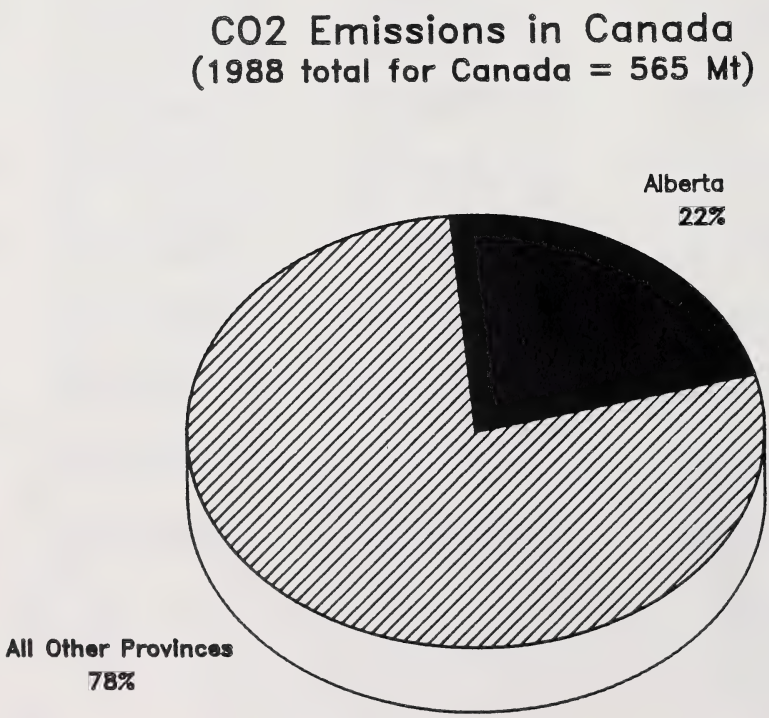

Figure 3

TABLE II - SUMMARY OF CO2 EMISSIONS BY SECTOR
(all numbers in Megatonnes of CO2)

i) By Sector - electric generation separate

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Residential	7.7	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.8	8.9	9.0	9.1	9.1	9.2	9.3	9.3	9.4
Commercial	5.1	5.2	5.3	5.4	5.6	5.7	5.8	6.0	6.1	6.2	6.3	6.4	6.4	6.5	6.6	6.7	6.8	6.9
Energy Industry	41.6	42.5	44.0	45.0	47.0	48.9	52.1	54.5	56.6	57.4	59.5	62.7	64.6	65.7	64.6	64.3	64.1	64.0
Other Industry	15.0	14.7	14.8	14.9	15.1	15.4	15.5	15.8	16.0	16.1	16.5	16.5	17.2	17.7	17.8	17.6	17.4	17.3
Transportation	19.6	19.7	19.7	19.8	20.0	20.3	20.6	21.0	21.4	21.8	22.3	22.4	22.5	22.7	22.9	23.1	23.4	23.6
Elec Generation	35.5	35.9	37.3	38.7	40.2	41.8	43.0	44.8	47.0	47.9	49.7	50.9	51.8	52.9	53.5	54.2	54.9	55.6
Total	124.3	125.8	129.1	131.9	136.1	140.3	145.5	150.6	155.7	158.1	163.1	167.9	171.7	174.8	174.5	175.1	175.9	176.8

ii) By Sector - electric generation allocated

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Residential	14.7	14.8	15.1	15.4	15.7	16.0	16.3	16.6	17.0	17.4	17.8	18.1	18.3	18.6	18.8	19.0	19.3	19.5
Commercial	14.9	14.9	15.4	15.8	16.3	16.9	17.3	17.7	18.5	18.9	19.6	20.0	20.4	20.9	21.2	21.7	22.2	22.7
Energy Industry	51.7	53.2	55.2	56.5	59.1	61.4	65.1	68.1	70.7	71.6	74.1	77.5	79.5	80.7	79.4	79.1	78.8	78.6
Other Industry	20.2	19.8	20.2	20.6	21.1	21.8	22.1	23.0	23.7	24.0	24.8	25.1	26.2	26.9	27.2	27.2	27.2	27.3
Transportation	19.6	19.8	19.8	19.9	20.1	20.4	20.7	21.1	21.5	21.9	22.3	22.5	22.6	22.8	23.0	23.2	23.5	23.7
Transmission Losses	3.3	3.3	3.5	3.6	3.7	3.9	3.9	4.1	4.3	4.4	4.5	4.7	4.7	4.8	4.8	4.9	4.9	4.9
Total	124.3	125.8	129.1	131.9	136.1	140.3	145.5	150.6	155.7	158.1	163.1	167.9	171.7	174.8	174.5	175.1	175.9	176.8

iii) By fuel type

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
fuel gas	47.8	48.0	49.7	51.0	52.9	54.9	57.8	60.6	61.5	62.2	63.0	64.7	65.8	66.1	65.7	65.4	65.2	65.1
process gas	4.8	5.3	5.2	5.4	5.4	5.5	5.5	5.5	5.7	5.7	5.9	5.7	6.0	6.6	6.3	6.3	6.3	6.3
feedstock gas	2.6	3.1	3.1	3.2	3.2	3.2	3.2	3.2	3.8	4.0	4.8	6.3	6.9	7.2	7.2	7.4	7.6	7.8
propane	2.3	2.3	2.3	2.4	2.4	2.4	2.5	2.5	2.6	2.6	2.7	2.7	2.8	2.8	2.8	2.9	2.9	3.0
diesel	6.7	6.8	6.9	6.9	6.9	7.0	7.1	7.2	7.4	7.5	7.7	7.8	7.8	7.9	7.9	8.0	8.1	8.2
kerosene	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
HFO	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
LFO	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
coke	4.2	4.0	3.9	3.5	3.6	3.7	3.7	3.7	3.7	3.7	4.2	4.6	5.3	5.4	5.4	5.4	5.3	5.3
synthetic crude	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
gasoline	11.8	11.8	11.6	11.7	11.7	11.8	11.9	12.0	12.2	12.3	12.5	12.5	12.4	12.4	12.4	12.4	12.4	12.4
aviation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
turbo	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.8	2.9	3.0	3.1	3.2	3.3	3.4
NGV	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.5
coal	34.6	34.7	36.1	37.5	38.9	40.5	41.7	43.4	46.3	47.1	49.2	50.5	51.3	53.0	53.5	54.2	54.9	55.6
raw CO2	5.8	5.8	6.0	6.2	6.6	6.8	7.4	7.6	7.7	7.8	7.9	7.9	7.9	7.8	7.6	7.3	7.1	6.8
non-energy CO2	1.3	1.3	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.7	1.7
total	124.3	125.8	129.1	131.9	136.1	140.3	145.5	150.6	155.7	158.1	163.1	167.9	171.7	174.8	174.5	175.1	175.9	176.8

As in the energy inventory, electric generation and the energy industry are both the largest CO_2 contributors and exhibit the largest increase over the period. Fuel gas is the largest contributor by fuel type at 47.8 Mt. Coal is a close second at 34.6 Mt, reflecting the significantly higher CO_2 emission factor per unit of coal energy combusted.

Figures 4 and 5 show the sectoral data graphically, for both 1988 and 2005. **Figure 4** displays as a separate quantity the CO_2 from electricity generation, which includes the CO_2 equivalent of electric transmission line losses. In **Figure 5** the CO_2 from electricity generation (35.5 Mt) has been allocated to the end use sectors. The result is a clearer view of the CO_2 contribution from the various sectors. Transmission losses are also shown as an "end-use" because of the difficulty in allocating transmission losses to a particular area. Note that the transportation, residential, commercial, and other industry sectors are all comparable in their CO_2 contribution when viewed in this manner.

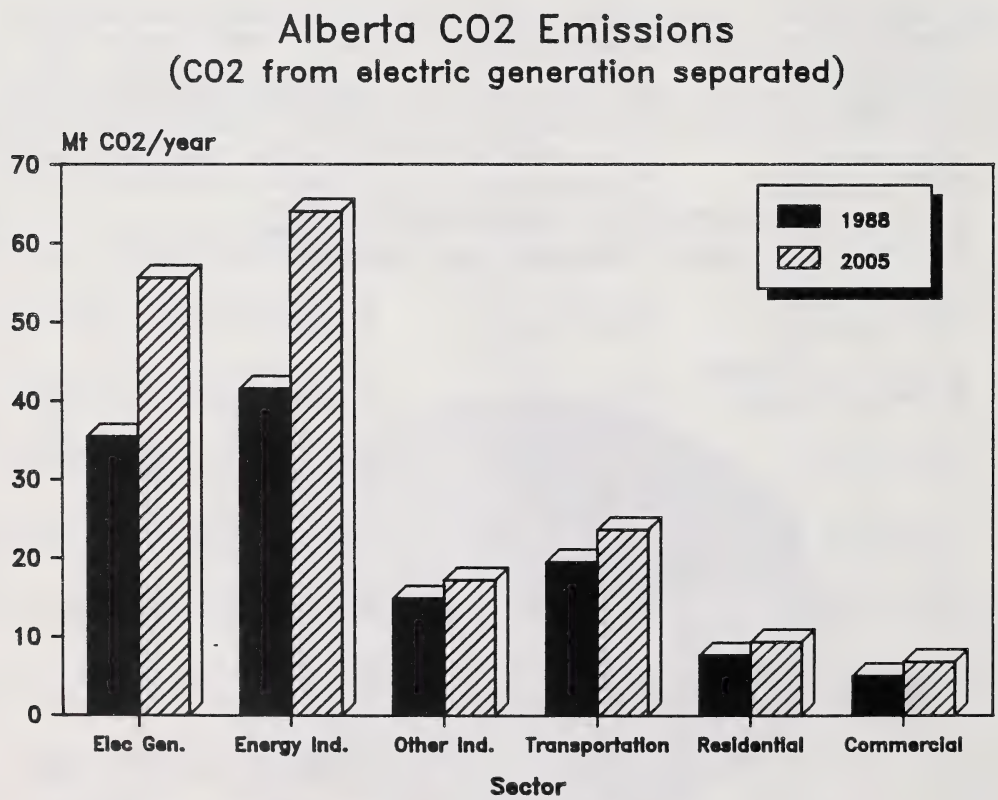

Figure 4

Figure 6 provides the breakdown of emissions by fuel type. Diesel emissions in the figure actually include diesel, kerosene, and heavy and light fuel oils. The "other" category refers to raw CO_2 from energy production and non-energy-related emissions.

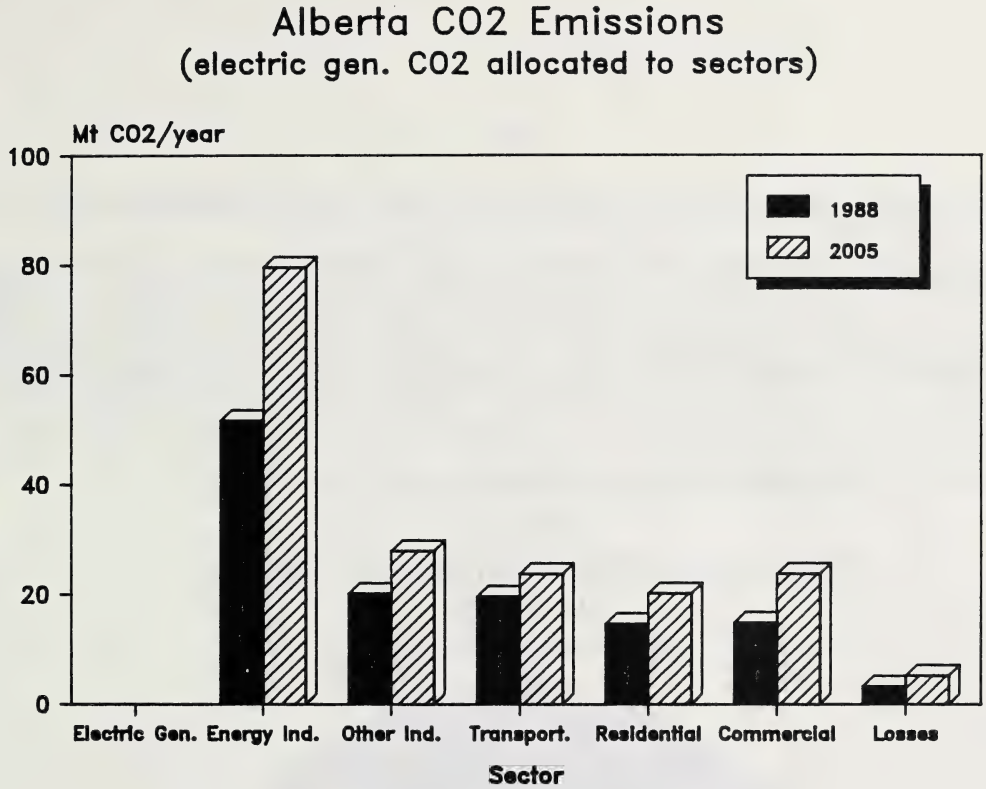

Figure 5

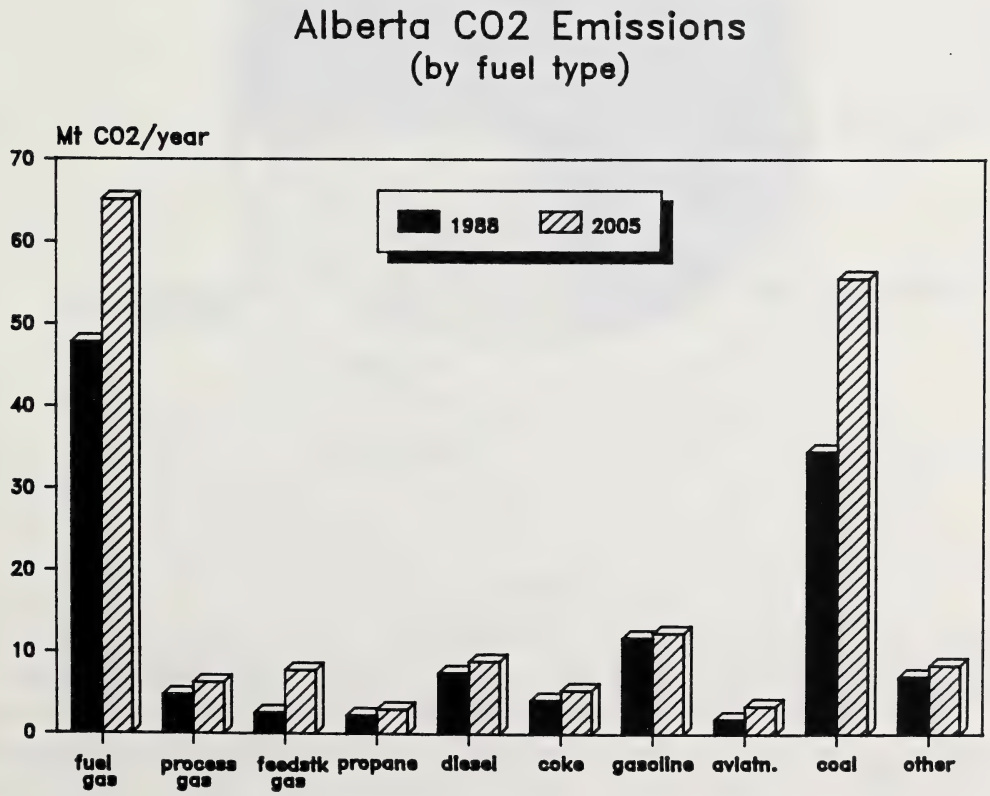

Figure 6

The following sections provide a more detailed review of carbon dioxide emissions on a sector-by-sector basis.

a) Residential Sector

The residential sector contributed 14.7 Mt of CO_2 in 1988. This includes emissions from residences of all types, including apartment buildings, as well as non-transport-related farm emissions from homes, buildings and irrigation energy use. Houses contribute 10.4 Mt in 1988 or 71% of the residential total. Apartments, both small walk-up and high rises, contribute 1.8 Mt or 12% of the residential total. The remaining 16% is from farm operations at 2.4 Mt. **Figure 7** shows the breakdown.

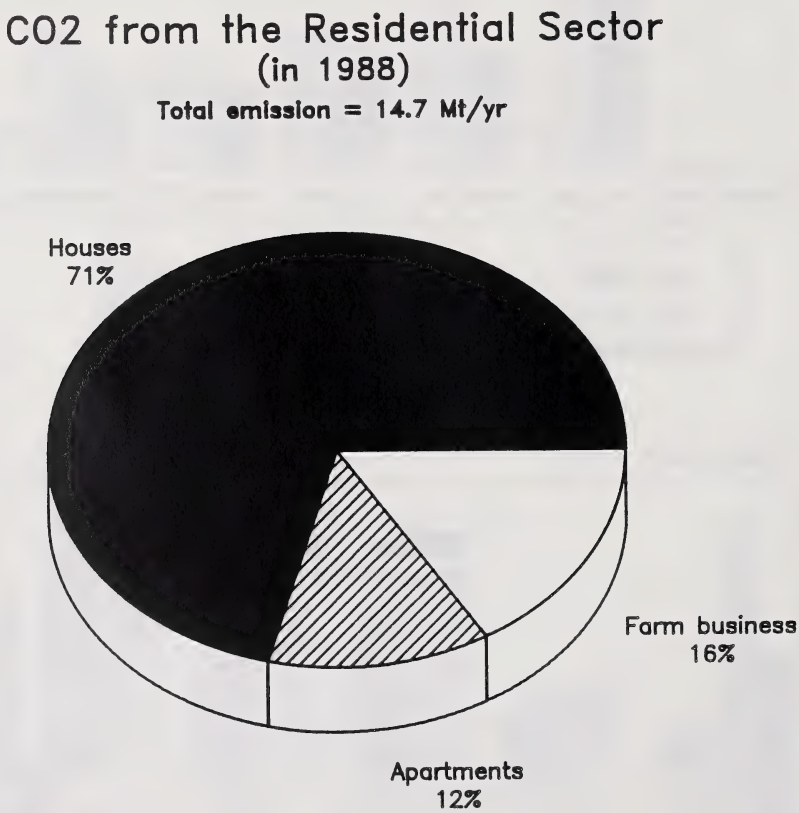

Figure 7

Within the residential sector the source of emissions is roughly equal between fossil fuel use (52%) and electricity (48%). Fossil fuels emission in this sector are almost entirely from natural gas, with small contributions from propane, fuel oil and coal.

Emission growth within the sector is estimated to increase by 33% to 19.5 megatonnes per year by 2005.

b) Commercial Sector

Commercial buildings, education facilities, hospitals, other commercial uses, and street lighting are included in this category which represents a total emission of 14.9 Mt/year in 1988. The largest subsector is commercial buildings contributing 8.7 Mt or 59% of the commercial sector total. Other commercial uses (a wide variety of light commercial energy demand) is second with 3.5 Mt or 23%, followed by education facilities (10%), hospitals (6%) and street lighting (2%). **Figure 8** shows the distribution.

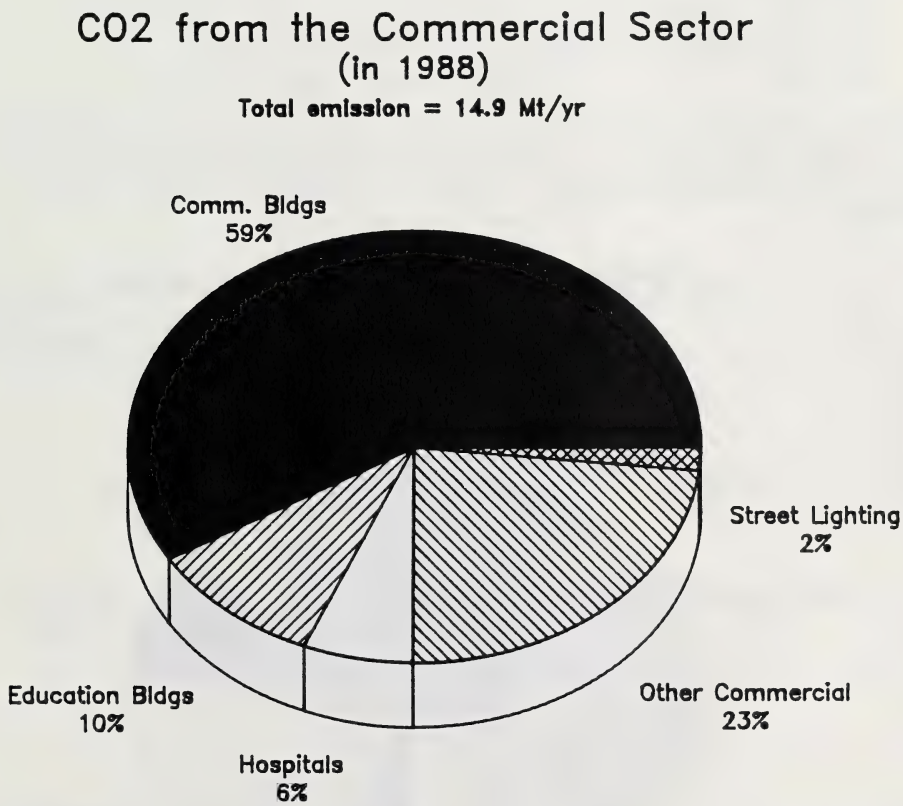

Figure 8

The commercial sector uses more electricity than fossil fuel. The result is that CO_2 emissions from electricity demand constitute 66% of the sector's emission total.

Emissions growth in this sector is estimated to be high, increasing by 52% from 14.9 to 22.7 Mt/yr in 2005. The largest portion of the increase is due to electricity use.

c) Energy Industry Sector

The energy industry sector is defined as the energy production subsectors within Alberta and is comprised of emissions from:

- oil sands
- coal mines
- gas processing and reprocessing
- pipeline energy use
- gas flaring
- raw CO_2 release from hydrocarbon production
- oil field operations, and
- refineries

Carbon dioxide emissions from this area total 51.7 Mt in 1988, growing to 78.6 Mt by the year 2005. The increase of 52% over the period is attributable largely to a forecast growth in the oil sands subsector of almost 20 megatonnes **Figure 9** shows the sector breakdown.

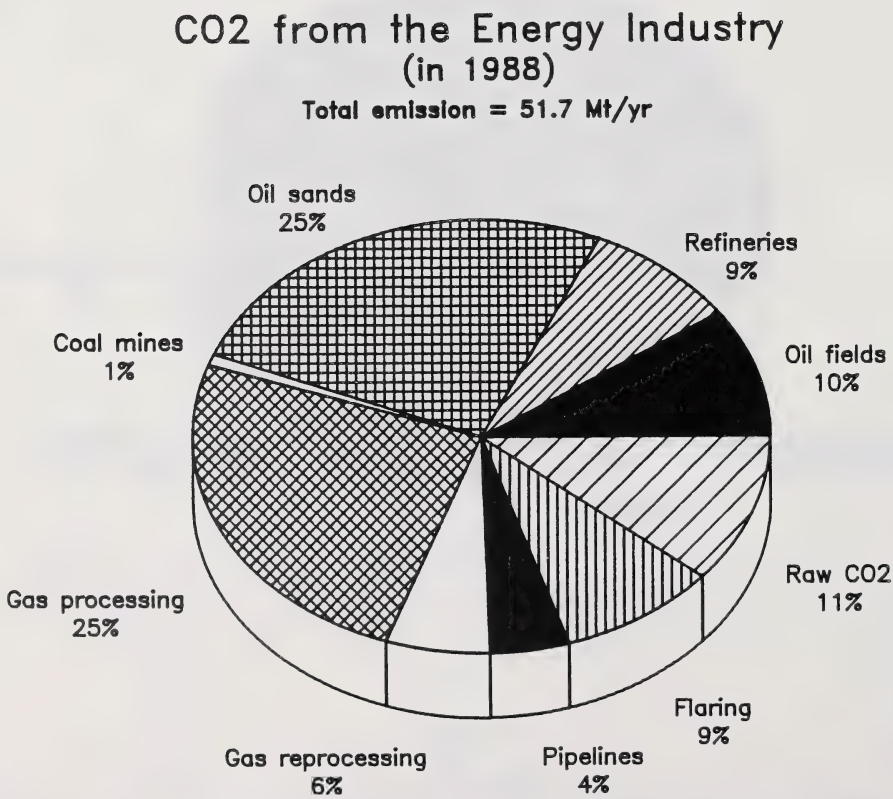

Figure 9

Emissions from oil sands operations in 1988 come from a variety of sources as shown in **Figure 10**. Chief among them is fuel gas (32%) and coke (28%) used in some cases to generate electricity. The total emission in 1988 from the subsector is 13.2 Mt. Note from **Appendix C** that all emissions from on-site electric generation in oil sands and other industrial areas are equated to zero. As mentioned earlier, this is done because the fuel is most often used in a cogeneration mode and the emissions are attributed for convenience to the non-electric portion of fuel use.

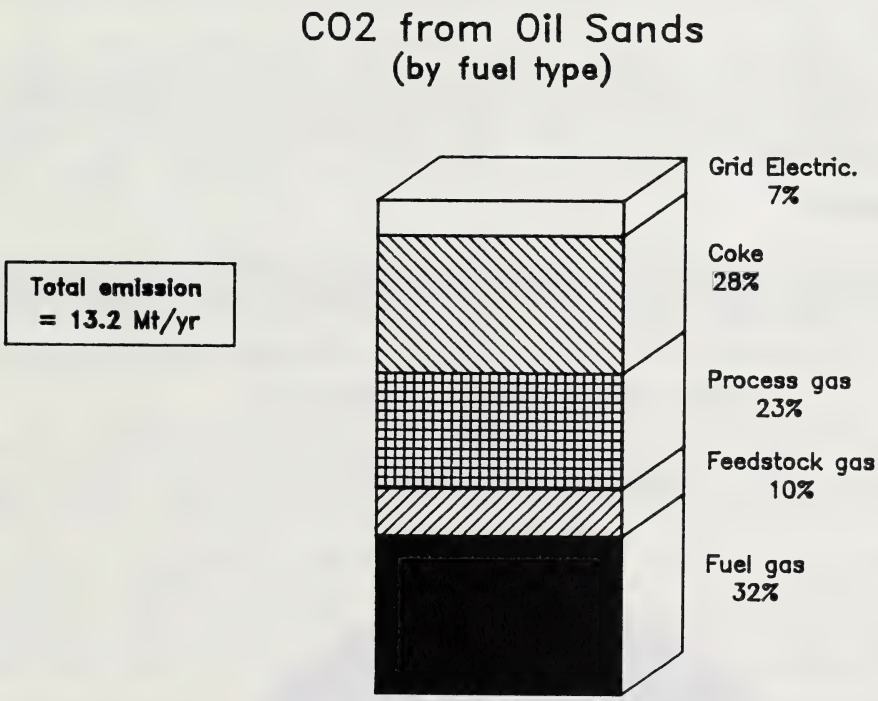

Figure 10

Coal mining contributed 0.43 Mt of CO_2 in 1988, mostly from electricity use.

Gas processing and reprocessing operations use large amounts of fuel gas and sizeable electricity resulting in a total 1988 CO_2 contribution of almost 16 Mt, the largest single industrial group. Fuel gas consumption includes field use, gathering systems, and gas plant fuel. The predicted growth is much less than the oil sands subsector, growing by about 30% by 2005.

Emissions from pipeline operations include both the utility and NOVA systems, and total 2.3 Mt in 1988. Emissions are largely from natural gas or electricity-fuelled compressor stations. Predicted growth is 30% over the forecast period.

Flaring of natural gas during production and well testing accounts for 4.6 Mt of CO_2 in 1988, growing to 5.08 Mt in 2005.

Raw CO_2 released directly to the atmosphere during natural gas production contributes 5.8 Mt in 1988 based on estimates of CO_2 concentration in gas fields done by the ERCB. As the overall average CO_2 content is not expected to change significantly in future, the annual emission rate is proportional to natural gas production. It is expected to increase to 6.8 Mt by 2005.

Oil fields generate CO_2 emissions mostly from electricity use, and gas and diesel combustion. The emission from this subsector is calculated to be 5.0 Mt in 1988, growing by only 10% by the year 2005 to 5.5 Mt. Oil refineries contribute 4.5 Mt in 1988, with little growth forecast by 2005.

d) Other Industry

The other industry category is made up of petrochemical operations, the manufacturing industry, cement plants, pulp and paper, and non-energy-related emissions. Together these activities contribute some 20.2 Mt of CO_2 per year in 1988. As seen from **Figure 11**, the petrochemical and the manufacturing industries dominate the bulk of emissions in the sector.

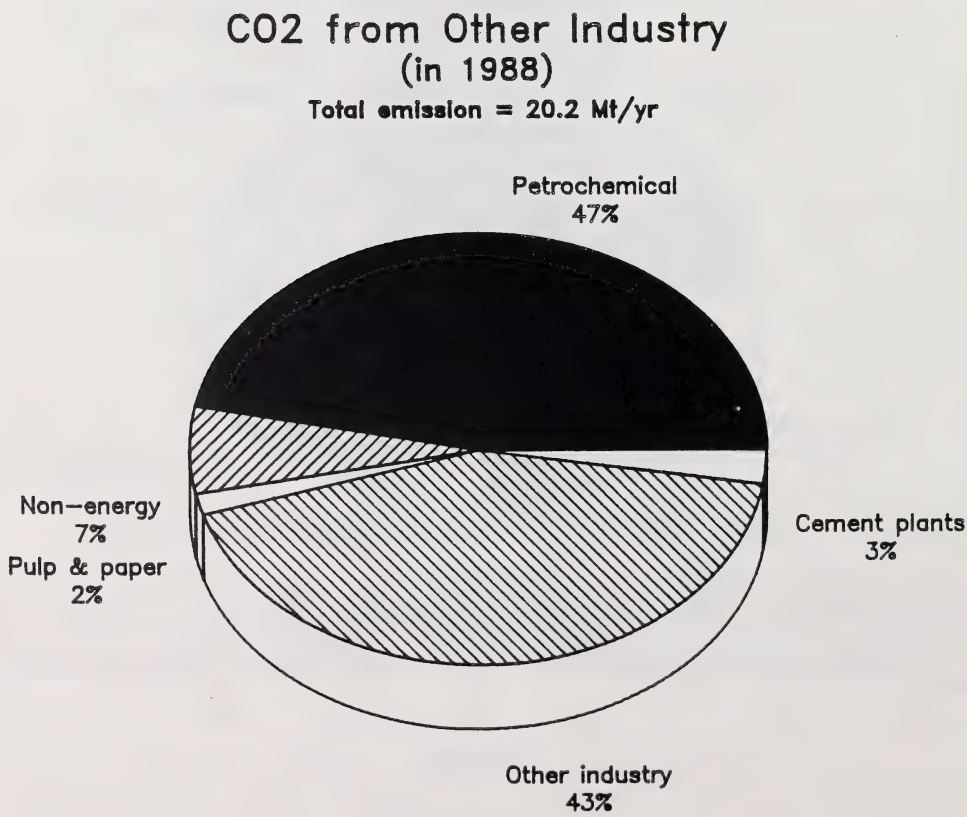

Figure 11

Petrochemical plants use substantial volumes of natural gas for both fuel and feedstock, and have relatively large electrical requirements. Carbon dioxide from feedstock is difficult to estimate because the amount released is process related. The bulk of these emissions is from carbon black and fertilizer plants. The total emission for the subsector is 9.4 Mt in 1988, increasing 9% to 10.3 Mt by 2005.

The manufacturing industry is poorly defined but is essentially comprised of all manufacturing and light industry not included in other sectors. Because of the nature of the ERCB's allocation of energy requirements, this subsector may also contain unattributed emissions from other areas. It should therefore be considered a "miscellaneous" category and the inventory figures used with some caution. In total it accounts for 8.6 Mt in 1988.

The pulp and paper industry generated 0.3 Mt of carbon dioxide in 1988 from fossil fuel combustion, including electricity. In fact, the industry produces more CO_2 through the use of wood waste as a fuel, and some operations are close to energy self-sufficiency in this regard. However, since this study does not include emissions from wood, the result is a relatively small emission level for the subsector. Growth for the subsector is predicted to be high according to the ERCB 1989 forecast, indicating an increase of over 13 times by 2005 to 4.0 Mt per year.

Cement plant emissions total 0.5 Mt in 1988. Also in the category are the non energy-related emissions due to CO_2 released from limestone in cement and lime production -about 1.3 Mt in 1988. A small additional amount is also released in magnesium production.

e) Transportation Sector

The transportation sector consists of emissions from commercial and public vehicles, rail and air transport, and farm vehicles. The re-categorization in this study is slightly different than that used by the ERCB, which also included pipeline energy use (allocated here to the energy industry sector), and electrical line losses (here treated as a separate sector).

Some re-categorization of the ERCB energy data was also done to get a clearer picture of vehicular emissions. Reporting of commercial versus public vehicle energy use is normally done on the basis of pump sales, although this can be misleading since many commercial vehicles are fuelled at public gas stations. With this in mind, the total vehicle energy requirement reported by the ERCB was subdivided on the basis of the province's vehicle stock.

Figure 12 shows the distribution of emissions from the transportation sector. Total emissions for the sector amount to 19.6 Mt in 1988, growing to 23.7 Mt by 2005.

Emissions from commercial and public vehicles are almost identical in 1988, totalling 7.9 Mt each. By 2005 emissions from commercial vehicles is predicted to have grown slightly more - to 9.1 Mt versus 8.5 Mt for public vehicles. Together they represent 80% of the transportation-related emissions.

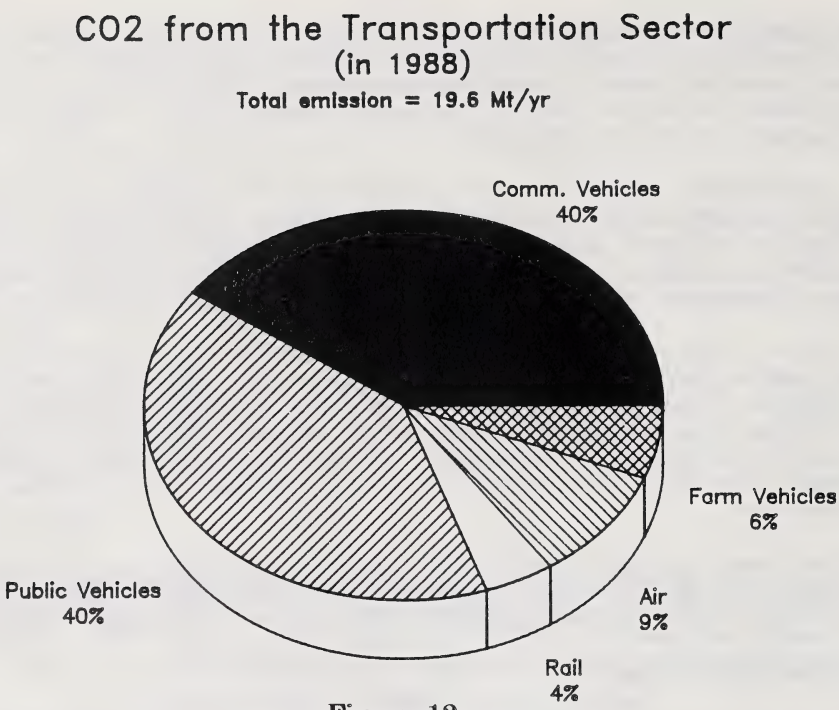

Figure 12

Rail emissions, mostly from diesel, are 0.9 Mt in 1988. Emissions from air traffic, primarily from aviation turbo fuel, are estimated to be 1.84 Mt. As aircraft emissions are calculated based on Alberta fuel sales, this number may be inaccurate because of aviation fuel sold but not burned in the province, or because of aviation fuel purchased elsewhere but burned within the province.

Farm vehicles using mainly diesel fuel contribute an additional 1.2 Mt of CO_2 in 1988. Emissions are predicted to reach only 1.22 Mt by 2005, due to assumptions of low growth in the agricultural sector.

f) Electric Transmission Losses

While not normally considered an "end-use" sector, transmission losses are defined as such for the purposes of this report. Doing so serves two purposes, first to facilitate future analysis of the potential for energy and emissions reduction from the transmission of electricity alone. Secondly, it allows the remainder of the emissions from electric generation, (that is the emissions from coal and natural gas used to produce electric energy which is ultimately consumed by the end use sectors), to be allocated to the end use sectors based on their secondary electric demand.

Emissions from electric generation energy use needed to offset transmission losses is estimated to be 3.3 Mt in 1988. Growth is roughly proportional to future electric demand, resulting in an emission level of 4.9 Mt by 2005.

g) Electric Generation

As previously discussed, emissions from central electricity generation facilities can be distributed to the other end use sectors relative to each sector's electric energy requirement. How this is done is detailed in **Appendix B.**

Total emissions from central electric generation in 1988 was 35.5 Mt. Approximately 97% of that was from coal-fired plants, the remainder from natural gas sources. Some small hydro-electric generation also occurs, but as it has no associated carbon dioxide emission it is not included in the calculation.

Emissions from this area are expected to grow by 57% to 55.6 Mt in the year 2005. Inherent in the forecast is no major change in either the fuel mix for generation or the efficiency of the generating plants.

4. DISCUSSION

The quality of data in this emissions inventory is directly tied to the energy requirements forecast as developed by the ERCB. It is important to recognize that the purpose of the ERCB report is primarily to predict energy requirements in all forms for the province, and using it as a model for an emissions inventory requires some data manipulation and leaves some gaps.

There are CO_2 emissions that are unaccounted for in this study. Wood used as a fuel, slash burning, and municipal incineration are the obvious ones. Other more subtle omissions occur, particularly in industry where additional fuel is often produced and used on site as a byproduct of the process. Numerous smaller emissions also occur for which there is no data, for example fuel used in petrochemical operations for catalyst regeneration.

There is also some degree of uncertainty about several of the CO_2 conversion coefficients, particularly the feedstock fuel and process gas factors. In order to more closely define emissions from these sources, a more detailed analysis of the industries involved is required. Also required is a closer investigation of CO_2 emissions from on-site electrical generation. In this area such variable factors as load, generation fuel mix, grid vs. on-site demand, and cogeneration all complicate the allocation of emissions to the various sectors.

If future emission reduction measures are to be investigated, it is vital to distribute emissions as accurately as possible to each sector. The approach of allocating electricity-related emissions to the sectors based on their electric demand is helpful in this regard. While the technique used leaves room for some error in allocation, it generally provides a clearer view of each sector's emission contribution to the total.

5. CONCLUSIONS

i) Alberta's total CO_2 emission in 1988 is estimated to be 124 Mt and is forecast to grow to 177 Mt by the year 2005. This makes the Alberta emission rate the highest per capita in Canada and the second largest overall in the country. The province accounts for about 22% of the Canadian total.

ii) By 2005 the majority of CO_2 emissions (over 70%) will be from those facilities or industries now in existence. This has significant implications if means for reducing emissions are considered.

iii) The largest source of CO_2 emissions is the energy industry, accounting for almost 42% of the 1988 total. When emissions from electricity use are allocated, the contribution from other sectors including residential, commercial, other industry and transportation is roughly equal at 12 to 16% of the total each.

iv) Growth during the period 1988 to 2005 is forecast to be over 40%. The growth rate assumes the ERCB high case scenario and would be less if slower economic growth and energy price increases are assumed. However, since CO_2 emissions from wood fuel are not included in the study, this has the counteracting effect of understating emissions growth.

v) There is a need for the development and maintenance of a provincial energy inventory done for the purpose of estimating CO_2 emissions. This implies more detailed statistics collection than is currently done for the ERCB requirements. Such information would also be useful for estimating emissions of other pollutants, for example oxides of nitrogen.

Appendix A
Energy Requirements by Sector

1988 to 2005

The table on the following page provides a detailed forecast of energy use in Alberta between 1988 and 2005. The only energy considered is that which results in one form or another in carbon dioxide emissions. The numbers are neither strictly secondary energy demand nor primary energy requirements.

The data for 1988 are actual statistics compiled from Statistics Canada reporting and other information from the ERCB. They are the most recent data available at the time of writing.

The 1989 to 2005 forecast is essentially taken from the ERCB Report 89-A - *Energy Requirements for Alberta 1988 to 2003*. In some cases when the 1988 actual data was applied to the forecast model, discrepancies were noted. In those instances the model was adjusted to better fit actual data. Those changes and additions are listed below.

Sector	Changes Made to ERCB 89-A Forecast
Residential	- propane demand was reduced by 3.3 PJ for all years based on recent ERCB revisions.
	- allocation of natural gas and electricity use to the three residential subsectors was made based on Alberta Energy energy use profiles.
Commercial	- propane demand increased by 3.5 PJ for all years based on recent ERCB revisions
	- allocation of natural gas and electricity use to the commercial subsectors was made based on Alberta Energy energy use profiles.
Industrial	- all on-site electricity production in GWh was re-allocated to natural gas fuel in the same subsector using a conversion of 10.5 MJ/KWh.
	- fuel gas use in the other industry subsector was increased by 30 PJ for all years to agree with 1988 actual data.
	- fuel gas use in the oil sands sector was increased by approximately 20 PJ for all years to account for solution gas used as lease fuel but not included in the 89-A report.
	- fuel gas use in the gas processing industry was assumed to be 7.0% of total marketable gas, broken down as: field use (2%), gathering system (1%) and processing plant (4%).
	- propane demand was increased by 12.3 PJ for all years.
Transportation	- commercial gasoline use was increased by 10 PJ and public vehicle gasoline use increased by 15 PJ for all years to better agree with 1988 actual data.
	- propane demand was increased by 1.7 PJ for all years.

APPENDIX A - Energy Requirements for Alberta (1988 - 2005)

Energy End Use Sector	Energy Requirements (fuels in PJs, electricity in GWH)																	
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
RESIDENTIAL SECTOR																		
Houses (urban & farm)																		
Gas	105.0	108.1	110.4	112.2	114.0	116.2	119.1	121.2	123.2	125.5	127.3	129.1	130.8	132.2	133.1	134.2	135.3	136.4
Coal	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
LFO	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Propane	2.8	2.9	2.9	2.9	3.0	2.9	3.0	3.1	3.1	3.2	3.2	3.3	3.3	3.4	3.5	3.5	3.6	3.6
Electricity (GWH)	5046	5258	5430	5598	5791	5988	6182	6379	6577	6788	6991	7158	7312	7474	7626	7772	7922	8074
Apartments																		
Gas	15.8	16.3	16.6	16.9	17.1	17.5	17.9	18.2	18.5	18.9	19.2	19.4	19.7	19.9	20.0	20.2	20.4	20.5
Electricity	1058	1102	1139	1174	1214	1256	1296	1337	1379	1423	1466	1501	1533	1567	1599	1630	1661	1693
Farms/Rural																		
Gas (business)	16.6	16.4	16.2	15.9	15.7	15.4	15.3	15.0	14.8	14.6	14.4	14.2	14.1	14.0	13.9	13.8	13.7	13.6
Gas (irrigtn)	4.2	4.1	4.0	4.0	3.9	3.8	3.8	3.7	3.7	3.6	3.6	3.5	3.5	3.5	3.5	3.4	3.4	3.4
Coal	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
LFO	1.0	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5
Propane	4.9	5.1	5.1	5.1	5.2	5.1	5.1	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3
Electricity	972	943	968	990	1012	1031	1049	1065	1082	1096	1115	1132	1149	1165	1178	1192	1206	1220
COMMERCIAL SECTOR																		
Commercial Bldgs																		
Gas	48.7	50.2	51.4	52.4	53.7	55.1	56.2	57.3	58.6	59.9	61.1	61.7	62.4	63.3	64.0	64.9	65.7	66.6
Electricity	6407	6807	7109	7406	7748	8077	8403	8735	9089	9443	9797	10046	10335	10638	10928	11254	11590	11936
Educational Bldgs																		
Gas	11.5	11.5	11.5	11.6	11.8	11.9	12.1	12.2	12.3	12.3	12.4	12.4	12.3	12.2	12.2	12.1	12.0	12.0
Electricity	938	950	962	976	1000	1027	1054	1081	1106	1131	1154	1172	1187	1203	1218	1231	1244	1258
Hospitals																		
Gas	7.7	7.9	8.1	8.3	8.5	8.7	8.9	9.2	9.4	9.6	9.9	10.1	10.3	10.6	10.8	11.1	11.3	11.6
Electricity	551	560	570	581	592	603	614	626	639	651	663	676	688	701	714	716	718	721
Other Commercial																		
Gas	25.1	26.3	27.0	27.9	28.7	29.6	30.3	31.1	31.8	32.7	33.3	33.8	34.1	34.7	35.0	35.6	36.2	36.8
Propane	6.3	6.3	6.5	6.6	6.9	6.9	7.2	7.3	7.4	7.5	7.8	7.9	8.0	8.0	8.1	8.1	8.2	8.2
LFO	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Electricity	1825	1578	1656	1732	1820	1905	1989	2074	2165	2256	2347	2412	2486	2564	2639	2723	2809	2898
Street Lighting																		
Electricity	266	283	282	285	289	299	307	317	326	335	344	350	357	363	369	374	380	386

APPENDIX A - Energy Requirements for Alberta (1988 - 2005)

Energy End Use Sector	Energy Requirements (fuels in PJs, electricity in GWH)																	
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
INDUSTRIAL SECTOR																		
Oil Fields																		
Gas	31.9	31.9	31.9	31.9	31.9	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.7	31.7	31.7	31.7	31.7
HFO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kerosene	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LFO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diesel	13.2	13.3	13.4	13.4	13.5	13.6	13.7	13.8	13.9	13.9	14.0	14.1	14.2	14.3	14.4	14.4	14.5	14.6
Electricity	2505	2803	2984	3114	3213	3291	3321	3348	3335	3341	3301	3316	3281	3274	3245	3202	3160	3119
Oil Refineries																		
Gas	26.2	25.6	25.5	25.5	25.7	25.9	27.0	28.4	29.1	29.1	29.2	29.2	29.2	29.3	29.3	29.3	29.2	29.2
Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coke	5.8	5.8	5.7	5.7	5.7	5.7	5.6	5.6	5.6	5.5	5.5	5.5	5.4	5.4	5.4	5.4	5.3	5.3
Process gas	32.9	32.7	32.6	32.4	32.2	32.0	31.9	31.7	31.5	31.4	31.2	31.0	30.9	30.7	30.5	30.3	30.2	30.0
Electricity	991	978	974	976	982	987	1015	1056	1075	1076	1079	1077	1076	1080	1079	1079	1079	1078
Oil Sands																		
Gas (fuel)	85.0	78.5	92.7	99.9	103.2	122.9	141.5	167.5	174.4	178.6	181.6	210.8	221.7	230.3	233.8	243.9	254.4	265.5
Gas (feedstock)	25.3	34.7	34.9	35.2	35.5	35.8	36.2	36.2	46.4	51.2	62.6	92.2	103.1	108.0	108.0	112.5	117.2	122.0
Process Gas	53.0	62.8	61.6	64.4	65.3	66.1	66.1	66.1	69.7	71.3	74.8	70.3	76.1	86.2	82.0	82.0	82.0	82.0
Coke	40.9	39.2	38.6	33.6	35.1	36.5	36.5	36.5	36.5	36.5	41.6	46.5	53.8	55.6	54.7	54.7	54.7	54.7
Coal	0.0	0.0	0.5	0.5	0.5	0.5	0.5	0.5	8.7	8.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7
Electricity (offsite)	947	963	1120	1183	1304	1537	1759	2058	2351	2456	2681	2838	2951	3034	3073	3162	3254	3348
Electricity (onsite)	1536	1669	1656	1680	1751	1785	1818	1818	2078	2199	2573	2992	3276	3416	3416	3416	3416	3416
Petrochemical																		
Gas (fuel)	106.7	96.1	96.1	96.1	99.2	103.1	103.1	109.0	110.1	110.1	111.1	111.1	122.7	122.7	122.7	118.4	114.7	111.6
Gas (feedstock)	232.3	252.4	252.4	252.4	252.4	252.4	252.4	246.4	258.8	258.8	305.2	305.2	322.9	322.9	322.9	316.4	310.0	303.8
Electricity (offsite)	2894	2629	2655	2674	2747	2872	2893	3301	3381	3401	3460	3459	3555	3571	3581	3475	3372	3272
Electricity (onsite)	1303	1196	1196	1196	1196	1196	1196	1196	1196	1196	1196	1196	1196	1196	1196	925	715	553
Gas Processing																		
Gas (field use)	41.4	42.2	43.0	43.8	44.6	45.4	46.2	47.0	47.8	48.5	49.3	50.1	50.9	51.7	52.5	53.3	54.1	54.9
Gas (gathering)	36.1	35.9	37.3	38.6	41.2	42.3	45.8	47.5	47.9	48.2	48.9	49.3	49.1	48.7	47.1	45.5	43.9	42.4
Gas (plant)	144.3	143.8	149.2	154.5	164.9	169.3	183.1	189.8	191.6	193.0	195.7	197.0	196.6	194.6	188.5	181.9	175.6	169.4
Electricity	1955	2445	2536	2628	2804	2880	3114	3228	3259	3282	3328	3351	3351	3351	3351	3351	3351	3351
Gas Re-Processing Plts																		
Gas (fuel)	10.4	14.8	15.3	15.9	17.2	17.6	19.3	20.0	20.0	20.1	20.2	20.0	19.6	19.3	18.5	17.4	16.4	15.4
Electricity	2554	2658	2757	2857	3048	3131	3385	3510	3543	3568	3618	3642	3634	3598	3485	3363	3246	3132
Coal Mines																		
Gas	0.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Electricity	402	408	426	445	466	488	507	531	561	575	598	615	630	651	663	678	693	709

APPENDIX A - Energy Requirements for Alberta (1988 - 2005)

Energy End Use Sector	Energy Requirements (fuels in PJs, electricity in GWH)																	
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
INDUSTRIAL SECTOR (CONT'D)																		
Pulp and Paper																		
Gas	3.5	4.5	6.3	6.4	6.7	7.0	7.0	7.0	7.6	7.5	7.8	8.1	8.1	4.5	4.6	4.6	4.6	4.7
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.4	6.4	6.4	6.4	6.4
Electricity (offsite)	148	341	534	728	921	1114	1307	1501	1694	1887	2080	2274	2467	2660	2853	3047	3240	3433
Electricity (onsite)	382	439	637	1017	1297	1449	1601	1601	1601	1601	1715	1867	1867	1867	1867	1867	1867	1867
Cement Plants																		
Gas	5.4	5.4	5.9	5.9	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.6	6.6	6.6	6.6	6.6	6.6
Electricity	254	249	270	270	270	275	280	285	290	295	300	306	306	306	306	306	306	306
Other Industries																		
Gas	94.5	95.0	95.3	95.6	95.9	96.2	96.4	96.6	96.7	96.8	96.9	97.0	97.1	97.2	97.2	97.3	97.4	97.5
Propane	15.8	15.9	15.9	16.2	16.3	16.8	16.9	17.0	17.3	17.4	17.5	17.6	17.7	17.8	17.9	17.9	18.0	18.1
HFO	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Kerosene	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
LFO	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Diesel	8.6	8.9	9.1	9.4	9.6	9.9	10.1	10.4	10.6	10.9	11.1	11.4	11.6	11.9	12.1	12.4	12.6	12.9
Misc.fuel	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Electricity (offsite)	2035	2141	2248	2354	2460	2567	2673	2779	2886	2992	3099	3205	3311	3418	3524	3630	3737	3843
Electricity (onsite)	182	193	196	199	202	206	210	214	218	222	227	232	237	243	249	255	261	267
Utility Pipelines																		
Gas	6.5	7.2	7.4	7.5	7.6	7.9	8.2	8.5	8.8	8.9	9.4	10.0	10.5	10.6	10.7	10.8	10.9	11.0
Electricity (oil)	776	798	827	827	830	840	839	849	847	824	820	848	849	845	818	801	783	766
Electricity (gas)	165	174	174	177	177	177	177	217	250	250	250	250	250	320	320	320	320	320
NOVA Pipelines																		
Gas	21.2	20.3	21.0	21.9	23.7	24.2	26.5	27.4	27.5	27.7	27.8	27.4	27.0	26.5	25.4	26.4	27.4	28.4
Gas Flaring	92.7	97.9	101.6	105.7	114.2	116.9	127.9	132.4	133.0	133.7	134.4	132.4	130.2	128.1	122.7	115.5	108.7	102.3
Raw CO2 Release	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX A - Energy Requirements for Alberta (1988 - 2005)

Energy End Use Sector	Energy Requirements (fuels in PJs, electricity in GWH)																	
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
TRANSPORTATION SECTOR																		
Commercial Vehicles																		
Diesel	46.8	46.2	47.0	46.0	45.5	45.8	46.5	47.4	48.8	50.2	51.4	52.1	52.3	52.4	52.2	52.5	52.8	53.1
Gasoline	62.5	62.5	61.7	62.0	62.3	62.8	63.6	64.3	65.1	65.9	67.0	67.1	66.9	66.7	66.6	66.6	66.6	66.5
Propane	5.1	5.3	5.4	5.6	5.7	5.9	6.0	6.3	6.4	6.6	6.8	7.1	7.3	7.6	7.9	8.2	8.5	8.9
NGV	0.1	0.1	0.2	0.4	0.5	0.8	1.0	1.2	1.4	1.6	2.1	2.2	2.8	3.5	4.6	5.0	5.5	6.0
General Public Vehicles																		
Diesel	4.4	4.5	4.4	4.4	4.5	4.5	4.5	4.5	4.5	4.5	4.6	4.6	4.5	4.6	4.5	4.6	4.6	4.6
Gasoline	107.7	107.7	105.8	105.9	106.1	106.8	107.8	108.9	110.1	111.1	112.8	112.9	112.4	112.3	112.1	112.2	112.2	112.3
Propane	2.7	2.9	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.5	3.7	3.8	3.9	4.1	4.2	4.4	4.6	4.8
NGV	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.7	0.8	0.8	1.2	1.2	1.5	1.9	2.5	2.7	2.9	3.2
Electric	68	71	74	79	82	83	84	85	86	88	89	90	92	95	98	98	99	99
Rail																		
Diesel	8.5	9.1	9.5	10.0	10.5	11.0	11.5	12.1	12.6	13.1	13.6	14.0	14.4	14.8	15.2	15.7	16.2	16.7
Synthetic crude	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Air																		
Avaition gasoline	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Turbofuel	25.3	26.1	27.6	29.1	30.9	32.6	34.0	35.4	37.0	38.3	39.6	39.8	41.1	42.5	43.6	45.0	46.5	48.0
Farm Vehicles																		
Diesel	13.4	13.8	13.7	13.8	14.0	13.9	13.9	13.9	13.8	13.8	13.8	13.8	13.6	13.7	13.7	13.8	13.8	13.9
Gasoline	3.7	3.8	3.7	3.6	3.5	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.5	3.5
ELECTRIC TRANSMISSION LOSSES																		
Transmission Losses	3327	3491	3646	3799	3968	4117	4267	4443	4632	4727	4888	5018	5100	5181	5235	5285	5336	5336
ELECTRIC GENERATION (PJs)																		
Coal	368.3	370.0	384.8	399.6	414.4	431.1	444.0	462.5	484.7	494.0	512.5	525.4	534.7	545.8	551.3	558.7	566.2	573.8
Gas	20.0	24.9	26.2	26.7	27.9	28.9	29.9	31.1	32.6	33.3	34.5	35.5	36.1	36.8	37.3	37.7	38.2	38.6
Total grid elec fuel (PJ) =	388.3	394.9	411.0	426.3	442.3	460.0	473.9	493.6	517.3	527.3	546.9	560.9	570.7	582.5	588.6	596.4	604.4	612.4
Total grid elec demand (GWH)=	36084	37632	39343	40853	42738	44543	46516	48806	50552	51885	53465	54733	55899	57056	57902	58689	59505	60298

Appendix B
CO_2 Conversion Factors

Burning fossil fuels results in carbon dioxide formation. The amount of carbon dioxide produced per unit of energy is a function of the type of fuel. In some cases, such as when fuel is used as feedstock, the amount of CO_2 produced is also dependent on the process.

The approach in constructing the CO_2 inventory was first to obtain a detailed energy use inventory and then convert the energy quantities to carbon dioxide using an appropriate conversion factor. The conversion factors are normally the fuel's higher or gross heating value assuming 100% combustion of hydrocarbons to carbon dioxide. The conversion factors used in the inventory are listed in the following table, in terms of kilotonnes of CO_2 per Petajoule of energy. Special cases are discussed afterward.

CO_2 CONVERSION FACTORS

Fuel	Factor (kt CO_2/Petajoule
Fuel Gas (assumes natural gas)	49.7
Propane (space heating and transportation)	59.8
Light Fuel Oil	73.1
Heavy Fuel Oil	74.0
Coal (sub-bituminous Alberta)	93.6
Kerosene	67.7
Diesel	70.7
Refinery Process Gas	51.0
Refinery Coke	86.0
Oil Sands Coke	89.4
Oil Sands Feedstock Gas	49.7
Oil Sands Process Gas	58.0
Petrochemical Feedstock	5.6
Flared Gas	49.7
Motor Gasoline	68.0
Synthetic Crude	70.0
Aviation Gasoline	69.4
Turbo Fuel	70.8

The factor used in converting electric demand to equivalent CO_2 emissions ranges from 0.983 to 0.923 kilotonnes of CO_2 per gigawatt hour. It is calculated for 1988 as follows:

- 1988 coal used for electric generation	=	368.3 PJ
- 1988 natural gas used for electric generatio	=	20.0 PJ
- total CO_2 emission from electric generation . . . . . (including hydro with zero CO_2 emission)	=	(368.3 x 93.6 kt/PJ) +(20.0 x 49.7 kt/PJ)
	=	35.5 Mt
- total electric demand in 1988 . . . . . (including line losses)	=	36,084 GWh
- Therefore the equivalent electricity-to-CO_2 conversion is . .	=	0.983 kt/GWh

The factor changes slightly each year of the forecast as the coal to gas fuel ratio changes for electricity generation. Thus the appropriate factor was calculated for each year and multiplied by the electricity use in each sector in that year to properly attribute CO_2 emissions to the sectors.

The emission factor used for oil sands process gas is somewhat empirical since its composition varies widely with time and location. The value of 58.0 kt/PJ was derived from a weighted average of the design process gas streams of both Syncrude and Suncor. No allowance for future change has been assumed.

A similar calculation was made to arrive at the value of 89.4 kt/PJ for oil sands coke.

Natural gas feedstocks can be converted to CO_2 via two processes in the petrochemical industry. The first is during steam reformation in the production of methanol and ammonia. The second occurs during the oxidation of residual carbon in the production of carbon black. Since large volumes of feedstock gas produce no carbon dioxide, it was necessary to first estimate the emissions of CO_2 from methanol, ammonia and carbon black operations, and then back-calculate a conversion factor (5.6 kt/PJ) that could be applied to the total known petrochemical feedstock volume. This method is subject to considerable error as changes occur in the petrochemical industry. However, as only a global forecast for total feedstock is available it was necessary to use this technique.

While not requiring a conversion factor, an estimate of the raw CO_2 released to the atmosphere was required. The ERCB made the estimate based on available information of CO_2 content in gas plant inlet volumes, CO_2 released from unprocessed gas used in field production, and CO_2 emitted from gas well testing, solution gas flaring and gas plant shut down flaring. The result was 5.8 Mt in 1988.

Appendix C
CO_2 Emissions by Sector

1988 - 2005

The detailed CO_2 inventory for the province is presented in the following table. All numbers are given in megatonnes of carbon dioxide.

Note that in some industrial subsectors where on-site electricity is generated, the CO_2 emissions are equated to zero. The electric energy requirement in each case has been allocated to the appropriate fuel in the same subsector at 10.5 MJ/KWh.

APPENDIX C - CO_2 Emissions Inventory for Alberta (1988 - 2005)

Energy End Use Sector	CO2 Emissions (Megatonnes CO2/year) 1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
RESIDENTIAL SECTOR																		
Houses (urban & farm)																		
Gas	5.22	5.37	5.49	5.57	5.66	5.78	5.92	6.02	6.12	6.24	6.33	6.42	6.50	6.57	6.61	6.67	6.72	6.78
Coal	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
LFO	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
Propane	0.17	0.17	0.17	0.18	0.18	0.17	0.18	0.18	0.18	0.19	0.19	0.20	0.20	0.20	0.21	0.21	0.21	0.22
Electricity	4.96	5.01	5.15	5.31	5.44	5.62	5.72	5.86	6.11	6.27	6.50	6.66	6.78	6.93	7.04	7.17	7.31	7.45
Apartments																		
Gas	0.79	0.81	0.83	0.84	0.85	0.87	0.89	0.91	0.92	0.94	0.95	0.97	0.98	0.99	1.00	1.00	1.01	1.02
Electricity	1.04	1.05	1.08	1.11	1.14	1.18	1.20	1.23	1.28	1.31	1.36	1.40	1.42	1.45	1.48	1.50	1.53	1.56
Farms/Rural																		
Gas (business)	0.83	0.82	0.81	0.79	0.78	0.77	0.76	0.75	0.74	0.72	0.72	0.71	0.70	0.70	0.69	0.69	0.68	0.68
Gas (irrigtn)	0.21	0.20	0.20	0.20	0.19	0.19	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.17	0.17	0.17	0.17	0.17
Coal	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
LFO	0.07	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Propane	0.29	0.30	0.30	0.31	0.31	0.30	0.31	0.32	0.32	0.33	0.33	0.34	0.35	0.35	0.36	0.37	0.37	0.38
Electricity	0.96	0.90	0.92	0.94	0.95	0.97	0.97	0.98	1.01	1.01	1.04	1.05	1.07	1.08	1.09	1.10	1.11	1.13
Total residential sector =	14.7	14.8	15.1	15.4	15.7	16.0	16.3	16.6	17.0	17.4	17.8	18.1	18.3	18.6	18.8	19.0	19.3	19.5
COMMERCIAL SECTOR																		
Commercial Bldgs																		
Gas	2.42	2.50	2.55	2.60	2.67	2.74	2.79	2.85	2.91	2.97	3.04	3.06	3.10	3.15	3.18	3.22	3.27	3.31
Electricity	6.30	6.49	6.74	7.02	7.28	7.58	7.78	8.02	8.45	8.72	9.10	9.35	9.58	9.86	10.09	10.39	10.69	11.01
Educational Bldgs																		
Gas	0.57	0.57	0.57	0.58	0.58	0.59	0.60	0.61	0.61	0.61	0.62	0.61	0.61	0.61	0.60	0.60	0.60	0.59
Electricity	0.92	0.91	0.91	0.93	0.94	0.96	0.98	0.99	1.03	1.04	1.07	1.09	1.10	1.12	1.12	1.14	1.15	1.16
Hospitals																		
Gas	0.38	0.39	0.40	0.41	0.42	0.43	0.44	0.46	0.47	0.48	0.49	0.50	0.51	0.53	0.54	0.55	0.56	0.58
Electricity	0.54	0.53	0.54	0.55	0.56	0.57	0.57	0.58	0.59	0.60	0.62	0.63	0.64	0.65	0.66	0.66	0.66	0.66
Other Commercial																		
Gas	1.25	1.31	1.34	1.38	1.43	1.47	1.50	1.55	1.58	1.62	1.66	1.68	1.70	1.72	1.74	1.77	1.80	1.83
Propane	0.37	0.38	0.39	0.39	0.41	0.42	0.43	0.44	0.44	0.45	0.47	0.47	0.48	0.48	0.48	0.49	0.49	0.49
RPPs	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Electricity	1.79	1.50	1.57	1.64	1.71	1.79	1.84	1.91	2.01	2.08	2.18	2.24	2.31	2.38	2.44	2.51	2.59	2.67
Street Lighting																		
Electricity	0.26	0.27	0.27	0.27	0.27	0.28	0.28	0.29	0.30	0.31	0.32	0.33	0.33	0.34	0.34	0.35	0.35	0.36
Total commercial sector =	14.9	14.9	15.4	15.8	16.3	16.9	17.3	17.7	18.5	18.9	19.6	20.0	20.4	20.9	21.2	21.7	22.2	22.7

APPENDIX C - CO2 Emissions Inventory for Alberta (1988 - 2005)

Energy End Use Sector	CO2 Emissions (Megatonnes CO2/year) 1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
INDUSTRIAL SECTOR																		
Oil Fields																		
Gas	1.59	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.57
HFO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kerosene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LFO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diesel	0.93	0.94	0.94	0.95	0.96	0.96	0.97	0.97	0.98	0.99	0.99	1.00	1.00	1.01	1.01	1.02	1.03	1.03
Electricity	2.46	2.67	2.83	2.95	3.02	3.09	3.07	3.08	3.10	3.08	3.07	3.09	3.04	3.04	3.00	2.96	2.92	2.88
Oil Refineries																		
Gas	1.30	1.27	1.27	1.27	1.28	1.29	1.34	1.41	1.45	1.45	1.45	1.45	1.45	1.46	1.45	1.45	1.45	1.45
Diesel	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coke	0.50	0.50	0.49	0.49	0.49	0.49	0.48	0.48	0.48	0.48	0.47	0.47	0.47	0.47	0.46	0.46	0.46	0.46
Process gas	1.68	1.67	1.66	1.65	1.64	1.63	1.63	1.62	1.61	1.60	1.59	1.58	1.57	1.56	1.56	1.55	1.54	1.53
Electricity	0.97	0.93	0.92	0.93	0.92	0.93	0.94	0.97	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99
Oil Sands																		
Gas (fuel)	4.23	3.90	4.61	4.96	5.13	6.11	7.03	8.32	8.67	8.88	9.03	10.48	11.02	11.45	11.62	12.12	12.64	13.19
Gas (feedstock)	1.26	1.73	1.73	1.75	1.76	1.78	1.80	1.80	2.31	2.54	3.11	4.58	5.12	5.37	5.37	5.59	5.82	6.07
Process Gas	3.07	3.64	3.57	3.73	3.79	3.83	3.83	3.83	4.04	4.13	4.34	4.08	4.41	5.00	4.76	4.76	4.76	4.76
Coke	3.66	3.51	3.45	3.00	3.14	3.26	3.26	3.26	3.26	3.26	3.72	4.16	4.81	4.97	4.89	4.89	4.89	4.89
Coal	0.00	0.00	0.05	0.05	0.05	0.05	0.05	0.05	0.81	0.81	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19
Electricity (offsite)	0.93	0.92	1.06	1.12	1.23	1.44	1.63	1.89	2.19	2.27	2.49	2.64	2.74	2.81	2.84	2.92	3.00	3.09
Electricity (onsite)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Petrochemical																		
Gas (fuel)	5.30	4.78	4.78	4.78	4.93	5.12	5.12	5.42	5.47	5.47	5.52	5.52	6.10	6.10	6.10	5.88	5.70	5.55
Gas (feedstock)	1.30	1.41	1.41	1.41	1.41	1.41	1.41	1.38	1.45	1.45	1.71	1.71	1.80	1.80	1.80	1.77	1.73	1.70
Electricity (offsite)	2.84	2.51	2.52	2.54	2.58	2.69	2.68	3.03	3.14	3.14	3.22	3.22	3.30	3.31	3.31	3.21	3.11	3.02
Electricity (onsite)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gas Processing																		
Gas (field use)	2.06	2.10	2.14	2.18	2.22	2.25	2.29	2.33	2.37	2.41	2.45	2.49	2.53	2.57	2.61	2.65	2.69	2.73
Gas (gathering)	1.79	1.79	1.85	1.92	2.05	2.10	2.28	2.36	2.38	2.40	2.43	2.45	2.44	2.42	2.34	2.26	2.18	2.11
Gas (plant)	7.17	7.15	7.41	7.68	8.19	8.42	9.10	9.44	9.52	9.59	9.73	9.79	9.77	9.67	9.37	9.04	8.73	8.42
Electricity	1.92	2.33	2.41	2.49	2.64	2.70	2.88	2.97	3.03	3.03	3.09	3.12	3.11	3.11	3.09	3.09	3.09	3.09
Gas Re-Processing Plts																		
Gas (fuel)	0.51	0.73	0.76	0.79	0.86	0.88	0.96	0.99	1.00	1.00	1.01	0.99	0.98	0.96	0.92	0.86	0.81	0.77
Electricity	2.51	2.53	2.62	2.71	2.86	2.94	3.13	3.22	3.29	3.29	3.36	3.39	3.37	3.34	3.22	3.10	2.99	2.89
Coal Mines																		
Gas	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Electricity	0.40	0.39	0.40	0.42	0.44	0.46	0.47	0.49	0.52	0.53	0.56	0.57	0.58	0.60	0.61	0.63	0.64	0.65

APPENDIX C - CO2 Emissions Inventory for Alberta (1988 - 2005)

Energy End Use Sector	CO2 Emissions (Megatonnes CO2/year) 1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
INDUSTRIAL SECTOR (CONT'D)																		
Pulp and Paper																		
Gas	0.18	0.23	0.31	0.32	0.34	0.35	0.35	0.35	0.38	0.37	0.39	0.41	0.40	0.23	0.23	0.23	0.23	0.23
Coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.60	0.60	0.60	0.60
Electricity (offsite)	0.15	0.33	0.51	0.69	0.87	1.05	1.21	1.38	1.57	1.74	1.93	2.12	2.29	2.47	2.63	2.81	2.99	3.17
Electricity (onsite)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cement Plants																		
Gas	0.27	0.27	0.29	0.29	0.29	0.30	0.30	0.31	0.31	0.32	0.32	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Electricity	0.25	0.24	0.26	0.26	0.25	0.26	0.26	0.26	0.27	0.27	0.28	0.29	0.28	0.28	0.28	0.28	0.28	0.28
Other Industries																		
Gas	4.70	4.72	4.74	4.75	4.77	4.78	4.79	4.80	4.81	4.81	4.82	4.82	4.82	4.83	4.83	4.84	4.84	4.84
Propane	0.95	0.95	0.95	0.97	0.97	1.00	1.01	1.02	1.04	1.04	1.05	1.05	1.06	1.06	1.07	1.07	1.08	1.08
HFO	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Kerosene	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
LFO	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Diesel	0.61	0.63	0.64	0.66	0.68	0.70	0.72	0.73	0.75	0.77	0.79	0.80	0.82	0.84	0.86	0.88	0.89	0.91
Synthetic crude	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Electricity (offsite)	2.00	2.04	2.13	2.23	2.31	2.41	2.47	2.55	2.68	2.76	2.88	2.98	3.07	3.17	3.25	3.35	3.45	3.55
Electricity (onsite)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Utility Pipelines																		
Gas	0.32	0.36	0.37	0.37	0.38	0.39	0.41	0.42	0.44	0.44	0.47	0.50	0.52	0.53	0.53	0.54	0.54	0.55
Electricity (oil)	0.76	0.76	0.78	0.78	0.78	0.79	0.78	0.78	0.79	0.76	0.76	0.79	0.79	0.78	0.76	0.74	0.72	0.71
Electricity (gas)	0.16	0.17	0.17	0.17	0.17	0.17	0.16	0.20	0.23	0.23	0.23	0.23	0.23	0.30	0.30	0.30	0.30	0.30
NOVA Pipelines																		
Gas	1.05	1.01	1.05	1.09	1.18	1.20	1.32	1.36	1.37	1.38	1.38	1.36	1.34	1.32	1.26	1.31	1.36	1.41
Gas Flaring	4.61	4.87	5.05	5.26	5.68	5.81	6.35	6.58	6.61	6.64	6.68	6.58	6.47	6.37	6.10	5.74	5.40	5.08
Raw CO2 Release	5.80	5.78	5.99	6.21	6.63	6.81	7.36	7.63	7.70	7.76	7.86	7.92	7.90	7.82	7.58	7.31	7.06	6.81
Non-energy CO2	1.32	1.34	1.36	1.38	1.40	1.43	1.45	1.47	1.49	1.51	1.53	1.55	1.57	1.60	1.62	1.64	1.66	1.68
Total industrial sector =	71.9	73.0	75.4	77.1	80.2	83.2	87.2	91.1	94.4	95.5	98.8	102.6	105.6	107.7	106.7	106.3	106.0	105.9

APPENDIX C - CO2 Emissions Inventory for Alberta (1988 - 2005)

Energy End Use Sector	CO2 Emissions (Megatonnes CO2/year) 1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
TRANSPORTATION SECTOR																		
Commercial Vehicles																		
Diesel	3.31	3.27	3.32	3.25	3.22	3.24	3.29	3.35	3.45	3.55	3.63	3.68	3.70	3.70	3.69	3.71	3.73	3.75
Gasoline	4.25	4.25	4.19	4.21	4.24	4.27	4.32	4.37	4.43	4.48	4.56	4.56	4.55	4.54	4.53	4.53	4.53	4.53
Propane	0.30	0.32	0.32	0.33	0.34	0.35	0.36	0.38	0.38	0.39	0.41	0.42	0.44	0.45	0.47	0.49	0.51	0.53
NGV	0.00	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.11	0.11	0.14	0.17	0.23	0.25	0.27	0.30
General Public Vehicles																		
Diesel	0.31	0.32	0.31	0.31	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.33	0.33
Gasoline	7.32	7.32	7.19	7.20	7.21	7.26	7.33	7.40	7.49	7.55	7.67	7.68	7.65	7.63	7.63	7.63	7.63	7.63
Propane	0.16	0.17	0.17	0.18	0.18	0.19	0.19	0.20	0.21	0.21	0.22	0.23	0.23	0.24	0.25	0.26	0.27	0.29
NGV	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.03	0.04	0.04	0.06	0.06	0.07	0.09	0.12	0.13	0.15	0.16
Electric	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09
Rail																		
Diesel	0.60	0.64	0.67	0.71	0.74	0.78	0.82	0.85	0.89	0.93	0.96	0.99	1.02	1.04	1.08	1.11	1.15	1.18
Synthetic crude	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Air																		
Avaition gasoline	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Turbofuel	1.79	1.85	1.95	2.06	2.19	2.30	2.41	2.51	2.62	2.71	2.81	2.82	2.91	3.01	3.09	3.19	3.29	3.40
Farm Vehicles																		
Diesel	0.95	0.98	0.97	0.97	0.99	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.96	0.97	0.97	0.97	0.98	0.98
Gasoline	0.25	0.26	0.25	0.24	0.24	0.24	0.24	0.24	0.24	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.24	0.24
Total transportation sector =	19.6	19.8	19.8	19.9	20.1	20.4	20.7	21.1	21.5	21.9	22.3	22.5	22.6	22.8	23.0	23.2	23.5	23.7
ELECTRIC TRANSMISSION LOSSES																		
Transmission Losses	3.27	3.33	3.46	3.60	3.73	3.86	3.95	4.08	4.31	4.36	4.54	4.67	4.73	4.80	4.83	4.88	4.92	4.92
TOTAL DEMAND-RELATED CO2 =	124.31	125.8	129.1	131.9	136.1	140.3	145.5	150.6	155.7	158.1	163.1	167.9	171.7	174.8	174.5	175.1	175.9	176.8
ELECTRIC GENERATION																		
Coal	34.48	34.63	36.02	37.40	38.79	40.35	41.56	43.29	45.37	46.23	47.97	49.18	50.04	51.08	51.60	52.29	53.00	53.71
Gas	0.99	1.24	1.30	1.33	1.38	1.44	1.49	1.55	1.62	1.66	1.71	1.76	1.79	1.83	1.85	1.87	1.90	1.92
Total generation sector =	35.47	35.9	37.3	38.7	40.2	41.8	43.0	44.8	47.0	47.9	49.7	50.9	51.8	52.9	53.5	54.2	54.9	55.6

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